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US Army Corps of Engineers

TECHNICAL REPORT EL-90-1

FISH RESOURCES AND WATER QUALITY OF AN IN-STREAM GRAVEL EXCAVATION PIT IN THE NAUGATUCK RIVER, CONNECTICUT

by

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January 1990

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for US Army Engineer Division, New England
424 Trapelo Road, Waltham, Massachusetts 02254-9149

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): Technical Report EL-90-1	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: USAEWES Environmental Laboratory; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code): 3909 Halls Ferry Road, Vicksburg, MS 39180-6199	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: USAE Division, New England; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code): 424 Trapelo Road, Waltham, MA 02254-9149	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Fish Resources and Water Quality of an In-Stream Gravel Excavation Pit in the Naugatuck River, Connecticut

12. PERSONAL AUTHOR(S)
Kasul, Richard L.; Killgore, K. Jack; Baker, John A.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ____ TO ____	January 1990	41

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Environmental stress; Gravel mining; Water quality; Fish inventory; Habitat alteration

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The fish assemblage and various water quality parameters were sampled during 18-22 July 1986, at a 1,550-m-long in-stream gravel excavation pit and three adjacent riffles located on the Naugatuck River about 6 km south of Thomaston, CT. The purposes of the study were to determine the quality of fish resources in the pit and to evaluate the potential of this habitat for supporting trout and Atlantic salmon.

Sampling took place during a low-water period when water quality was expected to most greatly stress the fish community. On 21 July, upstream water flowed into the pit with a temperature of 21.2° C, a dissolved oxygen concentration of 8.5 mg/ℓ, and an ammonia concentration of 0.70 mg/ℓ. Water quality conditions in the surface waters of the pit were similar to upstream water, but hypolimnetic water occurring in areas of the pit deeper than 5 m was found to have reduced dissolved oxygen (1.3 to 2.3 mg/ℓ) and elevated ammonia (to

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

19. ABSTRACT (Continued).

3.00 mg/ℓ) concentrations. High levels of total copper (0.02 to 0.04 mg/ℓ) were detected in water samples analyzed for heavy metals.

Eighteen species of fish were collected from the excavation pit and nearby riffles. The pit supported large numbers of yellow perch, largemouth bass, and white sucker. The adjacent riffles supported juvenile white sucker, juvenile largemouth bass, and small riverine taxa such as tessellated darter, longnose dace, blacknose dace, and fallfish. No trout were collected in the excavation pit or nearby riffle areas, but one specimen of a migratory species, the American eel, was collected in the pit. Fish collected for comparison from a headwater reach of the Naugatuck River approximately 30 km upstream from the excavation site included two additional species, brook trout and chain pickerel.

Benthic invertebrates collected from riffles above and below the pit included 23 and 24 taxa, respectively. Samples from both riffles were dominated by hydrophyschid caddis fly larvae. Next most abundant were mayflies in the upper riffle and midge larvae in the lower riffle. Hilsenhoff Biotic Index values of 5.1 in the upper riffle and 5.3 in the lower riffle were indicative of generally good water quality with some organic pollution.

During the low-flow summer period, water quality in the excavation pit appears to be marginal for trout and other coldwater species requiring relatively high dissolved oxygen concentrations and low water temperatures. While wastewater treatment has improved water quality conditions in the river, high levels of ammonia and copper persist. Current conditions are adequate to support piscivorous fishes such as yellow perch and largemouth bass. Introduced trout and salmon would probably experience high predation levels near the excavation site. The pits could probably be managed most successfully for lacustrine species in an overall management plan that included salmonid introductions in more suitable reaches of the river. Keywords are on previous page)

PREFACE

This research was conducted for the State of Connecticut, Department of Environmental Protection (DEP), under the authority of Section 22 of the Water Resources Development Act of 1974, Public Law 93-251 as amended, "Planning Assistance to States." The study was performed by the Environmental Laboratory, (EL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Project management and funding were provided by the US Army Engineer Division, New England (NED). This report was prepared by Messrs. Richard L. Kasul, K. Jack Killgore, and John A. Baker of the Aquatic Habitat Group (AHG), EL, WES. On-site assistance was provided by Messrs. Ernest Pizzuto and Art Mauger, DEP. Field sampling was conducted with assistance from Dr. Neil H. Douglas, Northeast Louisiana University, and Mr. Frank Ferguson, WES. Dr. Walter Whitworth, University of Connecticut, assisted in the taxonomic identification of fishes. Messrs. Pizzuto and Guy Hoffman, DEP, collected and processed benthic samples and calculated Hilsenhoff Biotic Index values for assessing levels of organic and nutrient pollution. The DEP provided laboratory analyses of water chemistry and heavy metals. Technical review of this report was provided by Dr. F. Douglas Shields, WES.

The work was performed under the direct supervision of Mr. Edwin A. Theriot, Chief, AHG, and Dr. Conrad J. Kirby, Jr., Chief, Engineering Resources Division, and under the general supervision of Dr. John Harrison, Chief, EL, and Dr. John Keeley, Assistant Chief, EL. The project monitor from NED was Mr. Lawrence Oliver, and the project manager from NED was Ms. Barbara Notini.

Commander and Director of WES was COL Larry B. Fulton, EN. Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

Kasul, Richard L., Killgore, K. Jack, and Baker, John A. 1990. "Fish Resources and Water Quality at an In-Stream Gravel Excavation Pit in the Naugatuck River, Connecticut," Technical Report EL-90-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

CONTENTS

FISH RESOURCES AND WATER QUALITY AT AN IN-STREAM GRAVEL EXCAVATION PIT IN THE NAUGATUCK RIVER, CONNECTICUT

PART I: INTRODUCTION

1. The Naugatuck River is a 65-km-long tributary of the Housatonic River that drains 800 sq km in western Connecticut (Figure 1). Cultural development in this watershed has caused changes in both the physical and biological resources of the Naugatuck River that may have contributed to the reduction or elimination of the salmonid fishery in portions of the river. Water quality is affected by the municipal discharge of poorly treated sewage and is additionally contaminated by industrial effluents (Mount, Norberg-King, and Steen 1986; Morrissey and Mauger 1988). Past mining of the riverbed for sand and gravel has resulted in the enlargement and deepening of some sections of the river, producing long in-stream pits that become virtually stagnant at low flows. At these times, the pits are thought to accumulate organic nutrients from discharge sources upstream that deplete dissolved oxygen and increase ammonia concentrations to levels that may approach or even exceed acute toxicity standards for Atlantic salmon and trout. As the water quality of the Naugatuck River improves through better treatment and regulation of wastewater, the reintroduction of salmonids is being considered; however, there remain concerns that poor water quality in the pits may hinder the establishment of a viable salmonid fishery.

2. The purpose of this study was to assess the quality of the fishery resource at an in-stream mining pit in the Naugatuck River during low flow conditions and to evaluate the feasibility of reintroducing salmonids into this reach of the river. This study examines an in-stream excavation pit, and three reaches of unexcavated stream channel consisting of riffle habitats located immediately upstream of the excavation pit, downstream of the pit, and between two of the three pools that form the pit. For comparison, a headwater reach was also examined. Specific objectives of the study were to measure water quality conditions in the excavated and unexcavated reaches of the river, measure and compare fish community composition in these areas, and assess the effect of the excavation pit on resident species of fish and on future salmonid introductions.

PART II: STUDY AREA

3. Fish collections and water quality measurements were obtained from three distinct habitats of the Naugatuck River: an in-stream excavation, three adjacent natural riffles, and a headwater reach.

4. The in-stream gravel excavation site was located south of Thomaston between the Penn Central Railroad bridge and the bend upstream of the Frost Bridge near Watertown, CT (Figure 1). This site is below Torrington in a reach where the fish community showed stress from upstream effluent sources (Mount, Norberg-King, and Steen 1986). The excavation consisted of two in-stream pools created by mining between 1963 and 1970, and a smaller connecting excavation that was dug between 1970 and 1980. Together, these three pools were identified as site 2 by MacDonald (1988) who determined that they extended through 1,550 m of river channel and increased average channel width from 53 to 59 m and average channel depth by more than 2 m to a maximum depth of approximately 7.6 m.

5. For this study, the three pit segments were designated the upper, middle, and lower pools (Figure 2). Water entered the upper pool from a 7-m-long riffle having substrate that varied from course gravel to large emergent boulders. Water depths ranged from a few centimetres to about 1.2 m. The upper pool and middle pools were separated by a shallow riffle about 25 m long running over a substrate of sand and fine gravel. A short, narrow constriction formed by an unexcavated section of shoreline separated the middle and lower pools. Water emerged from the lower pool over another shallow riffle about 40 m long. The three segments of riffle habitat were identified as the upper, middle, and lower riffles.

6. Also sampled was a site on the West Branch of the Naugatuck River above Torrington between the Reuben Hart and Stillwater Pond Reservoirs at Drakeville (Figure 1). This site, located about 30 km upstream of the Thomaston collection site, occurs near the headwaters of the Naugatuck River watershed, above the major sources of industrial and municipal pollution. Sampling took place in a reach approximately 100 m long that was mostly shallow (10-30 cm) with a fine gravel substrate and moderate current.

7. A summary of flow duration and daily discharge values in the Naugatuck River was compiled for two US Geological Survey (USGS) gaging stations on the Naugatuck, one located upstream of the excavation pit at Thomaston and the

second located downstream of the pit at Beacon Falls (Table 1). Flow duration values are cumulative frequency distributions of daily river discharges over a defined period of record. They are expressed as percent exceedance where flows greater than 10-percent exceedance level are high flows, the flow at the 50-percent exceedance level is the long-term median discharge, and flows less than the 90-percent exceedance level correspond to low-stream flow. Precipitation in the Naugatuck River watershed during 1988 was the lowest on record resulting in prolonged low flows throughout most of the summer months prior to sampling. Discharge at both gaging stations was less than the 90-percent exceedance on 10 July and less than the 75-percent exceedance throughout mid-July, indicating a low-flow condition in the two weeks prior to sampling. During the sampling period (18-22 July), rainfall caused a noticeable increase in water levels and discharge in the 25- to 50-percent exceedance range.

PART III: METHODS

8. The low-flow period of mid-summer was considered to be the time when poor water quality conditions would most greatly stress the fish community. Water quality sampling and fish collections were planned for this period and took place 18-22 July 1988.

9. Water quality conditions were measured at 11 sampling stations on 20 and 21 July. Stations were located as follows: one station in the upper riffle; three stations each in the upper, middle, and lower pools; and one station in the lower riffle (Figure 2). In the pools, surface and bottom samples were taken at all stations, mid-depth samples were taken where depth was sufficient, and vertical profiles were taken at two of the deepest stations. Measurements taken with a Hydrolab Model 201 water quality meter were temperature (°C), dissolved oxygen (mg/ℓ), pH, and conductivity (μmho). Field determinations of ammonia (mg/ℓ) were made on water samples collected with a Kemmerer Sampler and tested using a Hach DR-100 Colorimeter ammonia test kit. Turbidity measurements (NTU's), taken at the upper and lower riffles only, were made using a Hach Turbidimeter.

10. Six sets of additional water samples were collected with a Kemmerer Sampler on 21 July for the State of Connecticut Department of Environmental Protection (DEP) and analyzed by the Connecticut Department of Health Services on 18 August. Samples were taken from locations as follows: one set each from the upper and lower riffles, a surface and bottom set from the upper pool, and a surface and bottom set from the lower pool. The water samples were placed on ice for transport. Laboratory analyses were performed on each set of samples for solids (total, fixed, volatile, and total suspended), nitrogen (organic, ammonia nitrate, nitrite), 5-day biochemical oxygen demand (BOD), pH, hardness, chlorides, alkalinity, and total phosphorus, cadmium, chromium, copper, nickel, lead, zinc, arsenic, and mercury.

11. Fish were collected from the excavation pit by boat electroshocker gill net. The accessible shoreline of the three pools was sampled with a Coeffelt Model VVP-15 electroshocker operated in the direct current mode to obtain an output of 325-400 V and a current of 5-8 A. Gill nets collected fish from open-water areas of the pit; a total of eight net-nights were fished over a two-night period and were distributed as follows: two net-nights in the upper pool, two in the middle pool, and four in the lower pool. Fish were

removed from the nets in the upper pool after 3 hr of fishing on the first day to obtain fresh specimens for tissue analysis. They were then redeployed for the remainder of the night. The 61-m-long nets consisted of 15.2-m panels of six mesh sizes ranging from 1.3- to 7.6-cm square mesh. Nets were 4.6 m deep, secured to floats at the top, and fished from the surface. Fish collected by both electroshocker and gill net were identified to species, counted, and measured (total length). Catch per unit effort was calculated as fish per minute of electroshocking and fish per net night of sampling.

12. The upper and lower pools were also surveyed with hydroacoustics to remotely sample fish and to characterize in-pool physical habitat conditions. Acoustic sampling employed a scientific-grade sonar system from Biosonics, Inc. designed for freshwater fishery surveys. Sampling was conducted from a 4.3-m aluminum boat with a dual-beam transducer that was lowered into the water alongside the boat to a depth of approximately 0.3 m. A total of 33 transects were run across the width and along the length of the upper and lower pools to provide echo return information on fish located from about 1 m below the surface to near the bottom in a wedge-shaped volume of water that was narrowest at the top and widest at the bottom. Echo returns were plotted on continuous-feed chart paper, and were also tape-recorded for later processing. In the laboratory, echogram records of fish locations were digitized for analysis of spatial distribution. Acoustic sizes of fish were calculated from analysis of tape-recorded fish echoes using a Biosonics Model 181 Dual-Beam Processor and associated computer software. Measurements of acoustic size in decibels were converted to a rough approximation of fish size in centimetres using a regression equation described by Love (1971).

13. The riffle habitats adjacent to the excavation pit were more appropriately sampled with hoop nets and seine/backpack electroshocker. Hoop nets were fished overnight in the upper, middle, and lower riffles for two nights yielding total net nights of 4, 3, and 3 in the respective riffle segments. The nets were 4.6 m long and 0.9 m in diameter with 2.5-cm square mesh throughout. Twenty 9.3-sq-m plots were also sampled at each riffle site using a seine and backpack electroshocker. Samples were located in all parts of the riffle and included all available water depth and velocity conditions. Each sample was taken by stretching a 3-m seine with 0.6-cm mesh across the downstream end of the sample plot. Beginning at the upstream end of the plot, a backpack electroshocker was then guided over the entire plot area and stunned

fish were swept downstream by the current into the seine. Fish collected by both hoop nets and seine/shock methods were identified to species and counted. Those collected by hoop net were additionally measured for total length. Estimates of fish density calculated as fish per 9.3 sq m of stream area (shock/seine) and catch per unit effort (hoop nets) were calculated for each riffle area.

14. Benthic samples were collected by DEP from the upper and lower riffles on 9 August 1988, using a rectangular kick-net with 580-μm mesh. Two samples were collected from each riffle. One was collected from a 1-sq m area of stream bottom for analysis by the semiquantitative rapid assessment method (US Environmental Protection Agency (USEPA) 1987). The other was a thorough qualitative sample of all available habitat types. The qualitative sample included a sweep of submerged aquatic vegetation and collection of strongly attached organisms directly from submerged objects. Contents of the net samples were analyzed by DEP using methodology described by the USEPA (1987).

15. The Torrington site was sampled only for fishes using the same shock/seine method of collection employed in the riffle habitats adjacent to the excavation pit. A total of 21 samples were collected. Mean fish density (fish per 9.3-sq-m stream area) was computed from the sample data. A general characterization of the fishes at this site provided information for a background comparison of upstream and downstream fish community characteristics.

PART IV: RESULTS

Physical Measurements

16. Depth and bottom contour information in the pools was collected as part of the hydroacoustic sampling for fishes. Digitized measurements from echograms indicated that the deepest areas surveyed were 8.3 m (range to transducer plus 0.3 m transducer depth) in the upper pool and 6.8 m in the lower pool. Average depth across the width of the upper and lower pools was 4.2 and 3.9 m, respectively. The substrate in the pit, which ranged from gravel to clay, was heavily contoured by the excavation process. Echogram segments showing typical bottom contours across the pit at several positions along its length are shown in Figure 3.

Water Quality

17. Hydrolab measurements (temperature, pH, dissolved oxygen (DO), conductivity) and ammonia determinations were made over a 2-day period (Table 2). On 20 July, mean surface water values were 22.1° C, 5.7 mg/ℓ DO, 5.6 pH, 250 μmho conductivity, and 0.99 mg/ℓ ammonia. The surface measurements taken on 21 July were affected by an overnight rainfall that visibly raised the pool level by several inches. The additional inflow from rain runoff resulted in a lower mean surface water temperature (21.4° C), higher DO (7.3 mg/ℓ), higher pH (6.4), lower conductivity (181 μmho) and lower ammonia nitrogen concentration (0.77 mg/ℓ).

18. Temperature and DO profiles indicated that the pools were stratified where bottom depth was sufficient. Stratification was evident in all three pools on 20 July and persisted in the lower and middle pools on 21 July. Increased inflow from the overnight rainfall appeared to destratify the upper pool resulting in decreased ammonia and increased DO levels throughout the pool. At stations where stratification was evident, temperature dropped from about 20-25° C at the surface to 13-17° C at the bottom, and DO dropped from about 5-7 mg/ℓ at the surface to 1.3-2.3 mg/ℓ at the bottom (Table 2). The thermocline occurred at approximately the 5-m depth.

19. Ammonia concentrations were affected by stratification. Surface water measurements of ammonia taken with the Hach test kit were 0.7-1.3 mg/ℓ

at the surface and 1.00->3.00 mg/ℓ at the bottom (Table 2). Mean concentrations were 0.89 mg/ℓ at the surface and 1.65 mg/ℓ near the bottom. Water entering the pit at the upper riffle had an ammonia nitrogen concentration of 0.7 mg/ℓ, a level that was lower than most of the sampling stations in the three pools.

20. Chemistry results for the six water samples processed by the Connecticut Department of Health are presented in Table 3. Measurements are shown for solids (total, fixed, volatile, and total suspended), nitrogen (organic, nitrate, nitrite), 5-day BOD, hardness, chlorides, alkalinity, and total phosphorus, cadmium, chromium, copper, nickel, lead, zinc, arsenic, and mercury. Concentrations of total copper ranged from 0.02-0.04 mg/ℓ. These levels are similar to those previously recorded by DEP, levels that typically exceed USEPA acute criteria by approximately three times.* Laboratory determinations of pH and ammonia provided a quality check of the field measurements of these same parameters. Determinations of pH from field measurements were slightly lower than laboratory measurements, though trends for each were similar. Ammonia concentrations measured in the laboratory were somewhat lower than those from the field, though results from field and laboratory determinations broadly overlapped, and both indicated maximum ammonia concentrations >3.00 mg/ℓ.

21. The three pools encompass a reach of approximately 1,550 m of river channel. Two weak trends in water quality were apparent along the length of this reach. First, surface DO declined by amounts from 0.6-1.3 mg/ℓ from the upper to the lower pool. At the same time, surface and bottom concentrations of ammonia nitrogen tended to increase from the upper pool (0.65-1.10 mg/ℓ) to the lower pool (0.80->3.00 mg/ℓ).

22. Water entering the pit from the upper riffle was only marginally different from the surface waters of the upper pool, with lower temperature (21.2° C), higher DO (8.5 mg/ℓ), and the same ammonia (0.7 mg/ℓ). Water draining from the pit through the lower riffle had temperature (22.0° C) and DO (5.8 mg/ℓ) levels about midway between those of surface and bottom samples from the most downstream in-pit sampling station (Table 2), suggesting some degree of mixing of surface and bottom waters flowing out of the pit.

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* Personal Communication, 25 October 1988, Ernest Pizzuto, State of Connecticut, Department of Environmental Protection, Hartford, CT.

Fishes

23. A total of 1,392 fish representing 20 species were collected from the excavation pit, surrounding riffle habitats, and the Torrington sampling site. Common and scientific names for all species are provided in Table 4. The sampling effort accounted for a large number of the approximately 28 species of fish that have been historically documented in the Naugatuck River drainage area (Whitworth, Berrien, and Keller 1968).

Excavation pit

24. In the three pools forming the excavation pit, 484 fish from 12 species were collected by boat electroshocker and gill net. The boat electroshocker caught 200 fish in 50.3 min of sampling time, a catch rate of 3.98 fish/min. Eight gill net sets of approximately 24-hr duration caught 284 fish, a rate of 35.5 fish per 24-hr set.

25. The predominant species collected in the excavation pit were yellow perch (191), white sucker (119), largemouth bass (84), and pumpkinseed (28) (Table 5). Largemouth bass and pumpkinseed were collected exclusively by electroshocker in association with shoreline sampling; yellow perch were collected mostly from open-water habitat by gill nets; white sucker was captured in similar numbers in shoreline and open-water habitats. One specimen of a migratory species, the American eel, was also collected from the excavation pit. The pit was previously sampled in September 1984 by the Connecticut Fisheries Bureau using three gill nets that were fished overnight. This effort caught 140 fish from eight species including a 407-mm chain pickerel (*Esox niger*), a species not collected in this study.

26. A large percentage of the specimens collected from the excavation pit were adult-sized fish (Table 6). Size range and mean size (in parentheses) of the dominant species were: (a) yellow perch, 81-290 mm (302 mm), (b) white sucker, 54-405 mm (329 mm), (c) largemouth bass, 33-360 mm (72 mm), and (d) pumpkinseed sunfish, 66-195 mm (109 mm). The large overall sizes of fish partly reflect a selectivity bias of the sampling methods. A more representative sample of fish size was obtained using hydroacoustics. The acoustic sizes of 260 fish echoes ranged from a lower processing threshold of -58.5 dB (22 mm) to -26.2 dB (1,040 mm) and averaged -51.8 dB (46 mm). Acoustic sizes showed that the open-water habitat of the pit is numerically dominated by smaller-sized fish (Figure 4), providing a forage base for abundant

predators such as yellow perch and largemouth bass. Many of the smaller-sized fish may be juvenile yellow perch that typically school in open-water areas.

27. Fish distribution in the pit relative to stratification was measured with hydroacoustic data using digitized echogram measurements on fish position in the water column. The distribution of fish in the water column indicates that where water depth was less than 4.0 m, a large percentage of fish were usually found within 1.0 m of the bottom (Table 7). In water deeper than 4.0 m, more fish were found near mid-column and fewer near the bottom. This pattern was evident both in the upper pool, where no evidence of stratification existed on the day of sampling, and in the lower pool where stratification was still in place with the thermocline occurring at about a 5.0-m depth. In the lower pool, however, there appeared to be fewer fish near or below the thermocline level.

Riffle habitats

28. In the riffle areas immediately surrounding the pit, 895 fish representing 14 taxa were collected using two different sampling methods (Table 5). The shock/seine technique was most effective on small fish in shallow areas of the riffle habitat where 835 fish were collected. This method collected fish adapted to flowing water such as dace, fallfish, darters, and shiners, and also juvenile members of species abundant in the pit such as largemouth bass and white sucker. The predominant species collected by the shock/seine method were white sucker (368), longnose dace (119), tessellated darter (105), largemouth bass (97), and blacknose dace (81). Length measurements were not taken on these fish but nearly all were shorter than 40 mm.

29. Hoop nets fished the deeper, faster current areas of the riffles. They caught a total of 60 fish; predominant were rock bass (39), pumpkinseed sunfish (6), and smallmouth bass (6) (Table 4). The smallmouth bass were all captured from a single net set from the lower riffle. Sizes of these fish (mean in parentheses) were: (a) rock bass, 130-230 mm (166 mm), (b) pumpkinseed sunfish, 130-200 mm (164 mm), and (c) smallmouth bass, 215-230 mm (223 mm) (Table 6).

30. Fish collected in the upper, middle, and lower riffles each included 2-3 species collected in hoop nets and 8-9 species by shock/seine sampling at each site. The three riffle sections had similar species assemblages. In seine/shock sampling, the mean number of fish per 9.3-sq-m plot

(+SD) was 6.33 (5.12), 28.95 (54.07), 7.25 (4.01) in the upper, middle, and lower riffles, respectively (Table 8). The higher density of fish in the middle riffle was mostly due to large numbers of juvenile white sucker and largemouth bass. Catch per net night (hoop nets) averaged 0.50 (0.58), 10.33 (8.02), and 9.00 (13.86) in the three riffle sections. Much of the higher catch in the lower and middle riffles was due to large numbers of rock bass.

31. The lower riffle was sampled in 1983 as part of a larger sampling effort of the Naugatuck River conducted by the USEPA (Mount, Norberg-King, and Steen 1986). Using backpack electroshocking, 17 fish representing 5 species were collected from the riffle identified as station N6, including the chain pickerel, which was not collected in this study.

Torrington

32. Eleven species of fish were collected by the shock/seine method from the West Branch of the Naugatuck near Torrington. Two of these, brook trout and chain pickerel, were not collected from either the pool or riffle habitats at the Thomaston collection site. A total of 133 fish were collected; the most abundant were largemouth bass (52) and tessellated darter (28). Mean (+SD) number of fish per 9.3-sq-m plot was 5.55 (5.28) (Table 8). This was similar to the mean fish density observed in the upper and lower riffles near Thomaston.

Benthic Invertebrates

33. The total numbers of invertebrate taxa collected from the upper and lower riffles were 23 and 24, respectively (Table 9). Samples at both sites were numerically dominated by hydrophychid caddis fly larvae, followed by mayfly larvae in the upper riffle and midge larvae in the lower riffle. The samples notably lacked taxa in the orders Plecoptera, Ephemeroptera, Trichoptera, and Coleoptera that are considered to be sensitive to pollution. Based on the Hilsenhoff Biotic Index, which uses the tolerance level of arthropods to index organic and nutrient pollution, the pollution levels were 5.1 in the upper riffle and 5.3 in the lower riffle. These levels indicate good water quality with some organic pollution (Hilsenhoff 1987). The most likely water quality factor affecting the benthic community was copper, which was found to be present at elevated levels (Table 3).

PART V: DISCUSSION

34. The pit and adjacent riffles provide both lacustrine and riverine habitats that support a diverse fish assemblage. Lacustrine-oriented species that were commonly found in the pit were yellow perch, largemouth bass, and pumpkinseed, all of which are represented by various year classes indicating reproductive success and recruitment of harvestable adults. This can be partly attributed to the increased depth and size of the pit over normal channel dimensions, to wastewater enrichment, and to extensive amounts of both shoreline and bottom cover.

35. Species collected that generally inhabit flowing water included common shiner, chubs, dace, white sucker, redbreast sunfish, rockbass, and tessellated darter. Although many of these species are highly adaptable (particularly the adults) most prefer flowing water and gravel substrate for spawning, incubation of eggs, or rearing of juveniles. In streams, the longnose dace, for example, spawn only in riffles with a velocity of 45 to 60 cm/sec. The fry become pelagic after hatching and move to protected margins of quiet shallow water, and later move back to swift areas with a velocity greater than 45 cm/sec (Bartnik 1970). Similarly, embryos of creek chubs require flowing water for adequate oxygen exchange but after emerging from the redds, the fry move to shallow areas long the edges of pools (Copes 1978). Therefore, the combination of the pit and adjacent riffles creates a contiguous environment that can support all life stages of many fishes that require different habitat conditions to successfully complete their life cycle.

36. No trout were collected from the pit or the adjacent riffles. Given the extensive sampling effort, the failure of trout to appear in any samples indicates that, if present at all, they were extremely rare. Earlier fish collections made by USEPA (Mount, Norberg-King, and Steen 1986) in August 1983 and the Connecticut Fisheries Bureau in September 1984 also failed to document any trout in the pit though both studies found trout elsewhere in the Naugatuck River drainage area. These included a brown trout (*Salmo trutta*) collected by USEPA on the Mad River below Waterbury and a brown trout and a brook trout (*Salvelinus fontinalis*) collected by the Connecticut Fisheries Bureau from a gravel excavation on the Naugatuck River near Harwinton, above Thomaston. This site was apparently located upstream of the major wastewater discharge sources near Thomaston (Mount, Norberg-King, and Steen 1986).

37. Although the pit and adjacent riffles provide suitable habitat for warm- and cool-water species, high summer surface temperatures (>20° C) in the pit may hinder establishment of a permanent salmonid fishery in this reach of the Naugatuck River. The upper limit (near lethal) water temperature for brown trout is 27° C, at which point naturally reproducing, viable stream populations would not be maintained (Raleigh, Zuckerman, and Nelson 1986; Needham 1969). Optimal temperature requirements for good growth and survival are 12° to 19° C (Mills 1971, Tebo 1975). Brook trout usually do poorly in streams where water temperature exceeds 20° C for extended periods, while the optimum temperature range is 11° to 16° C (Raleigh 1982 and references therein). Adult stream rainbow trout generally select temperatures between 12° and 19° C (Garside and Tait 1958; Bell 1973; Cherry et al. 1977; McCauley, Elliot, and Read 1977). In contrast to temperature, the slightly acidic to neutral pH measurements were within the tolerance limit of most trout. Trout occur in a pH range of 5.0 to 9.5 with an optimal range of 6.5 to 8.0 (Hartman and Gill 1968, Marshall and MacCrimmon 1970).

38. The pit also appeared to affect other water quality conditions. The virtually stagnant water at low flow permitted stratification to occur in deeper portions of the pit where low DO (<5 mg/ℓ) and high ammonia concentrations (up to 3.00 mg/ℓ) were measured below the thermocline. It is doubtful that stratification caused any serious habitat loss for resident species in the pit because the area of hypolimnion was relatively small, and extensive areas of warmer water were available above the thermocline. In fact, the numerous targets detected by hydroacoustics near the bottom were probably white suckers that commonly feed along the substrate and have a wide tolerance of water quality conditions (Twomey et al. 1984), whereas schools of juvenile yellow perch, which are quite ubiquitous, probably comprised many of the surface and midwater targets.

39. Stratification would represent a more serious loss of habitat for trout, which would be precluded from using the colder waters below the thermocline because of low DO levels. Salmonids require relatively high DO levels for growth and survival. Trout avoid waters with oxygen levels below 5 mg/ℓ (Mills 1971) and the incipient lethal level is approximately 3 mg/ℓ (Burdick et al. 1954; Doudoroff and Shumway 1970). The concentrations of ammonia occurring below thermocline would also be toxic to brown and brook trout (1.26 mg/ℓ), but exposure to low DO would probably keep them above the

thermocline where ammonia concentrations were only slightly greater than ambient levels upstream.

40. The length of the pit may affect the degree of water quality degradation. There was a gradual downstream reduction in DO and increase in ammonia. This was probably due to the deeper waters and reduced hydraulic circulation in the lower pit. However, the degradation was not substantial and did not appear to adversely affect either the resident fish community or benthic invertebrates in the riffle below the pit, as sampling indicated a diversity and density of organisms similar to the upstream riffle. Since this is one of the longest excavations on the Naugatuck River, other areas would be less affected.

41. Successful reintroduction of Atlantic salmon into the Naugatuck River depends on overcoming possible obstructions to migration as well as improvement in water quality. If the effect of migration barriers were minimized, adult Atlantic salmon entering the excavation site in the fall to spawn would find that the adjacent riffles had suitable substrate for nest construction and egg deposition. During their early growth period in the summer subsequent to emergence, older parr are generally residents of deeper pools (Danie, Trial, and Stanley 1984; Gibson 1966), and would be expected to inhabit the excavation pit. There they would be exposed to potentially poor water quality conditions in the pits including ammonia that becomes toxic to this species at a concentration of about 0.86 mg/ℓ. Growth and production of juveniles are optimum at water temperatures of 15° to 19° C, but Atlantic salmon will tolerate temperatures up to 27° C, above which they move to colder water (Danie, Trial, and Stanley 1984; Decola 1975). In addition, streams with DO concentrations below 5 mg/ℓ are usually not inhabited by salmon (Danie, Trial, and Stanley 1984). Therefore, although the pits provide a unique deep-water habitat for parr, they would have to tolerate relatively high temperatures in the upper water column of the pit, as well as high ammonia and low DO levels near the bottom, or move to shallower areas of the pit or to other reaches of the Naugatuck River.

42. Parr salmon and trout inhabiting or migrating through the pit would be subjected to predation by piscivorous fishes. The high reproductive rate of yellow perch, as well as their voracious appetite and foraging efficiency, can lead to serious competition with species such as trout (Scott and Crossman 1973). Adult largemouth bass are highly piscivorous, and because of their

high relative abundance in the pit, can also become major predators on salmonids. Predation and competition are negative effects on salmon and trout that would likely be localized near the excavation pits. The pits would not likely jeopardize the river's entire salmonid fishery. The impact on salmonid abundance cannot presently be predicted in quantitative terms, but the relative high abundance of piscivorous fishes in the pits should be considered in any future management program.

43. This study addressed habitat and fish community structure during the period of the year when water quality conditions were expected to be at their yearly worst. Because of the stochastic nature of flowing water environments, habitat quality during other months may also be limiting to fishes, especially salmonids that generally require a more pristine environment than the many ubiquitous species that presently occur in the Naugatuck River. These factors include adequate water depth over the riffles that would not impede migration, suitable spawning substrate, and an abundant food supply following emergence of fry from the redds. However, excavation pits are unique in that they provide deep water pools near natural riffles. Water quality conditions are suitable for sport species such as largemouth bass and yellow perch so that management for these species is practicable. The introduction of trout is certainly not limited by the physical habitat that exists in the pits and surrounding riffles, but it may be difficult to sustain viable adult populations during low flow conditions because of marginal water quality conditions.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

44. The excavation pit supports a relatively large number of lacustrine sport fishes including yellow perch, largemouth bass, pumpkinseed, and rock bass. Based on the range of size classes of these species, reproductive population probably exists in this reach of the Naugatuck River (Carlander 1969, 1977). Their abundance and size have benefited from the deep-water pool habitat created by dredging. The present fishery in the pit does not appear to be seriously affected by water quality during summer low-flow periods. Suitable water quality characteristics, including DO, exist throughout much of the pit during low-flow periods sufficient to maintain the predominant species found there.

45. During summer low-flow periods, water temperature and DO are outside the optimal range for most species of salmon and trout, and ammonia levels can exceed tolerance limits. These conditions may hinder the establishment of a successful trout fishery in the excavation pit, though chances should increase with further improvements in water quality resulting from regulatory and cleanup measures. The establishment of a self-sustaining or put-and-take salmonid fishery may also be affected by species such as yellow perch and bass that can be expected to prey on salmonid parr. This problem would not exist in unexcavated portions of the river where piscivorous fish are probably not as abundant.

46. Water in the pit was stratified in the few areas where bottom depth was greater than about 5 m. Water temperature was most suitable for trout below this level (12° to 17° C), but low oxygen (1.2 to 2.3 mg/ℓ) and high ammonia levels (up to 3.00 mg/ℓ) would preclude utilization of this portion of the pit by trout and most other species. Above thermocline level, water quality was similar to inflowing water, but toward the downstream end of the pit, it declined slightly with higher temperature and ammonia and lower DO. These characteristics slightly reduced the quality of the water flowing out of the pit but did not noticeably affect fish populations in the riffle area immediately below the pit.

47. Water quality in the pit is affected by discharge. Prolonged low flows move too little water through the pit to prevent increased temperature and ammonia and reduced DO. Neither the frequency of occurrence nor the duration of reduced water quality conditions in the pit are known, but the

magnitude of water quality effects does not appear to be large. It is also apparent that summer rains that temporarily raise flow to the 25 exceedance level help to destratify the water in the pit and improve its overall quality. Measures to improve water quality in the pit during low-flow periods would probably not greatly benefit the lacustrine fish presently in the pit, but might benefit salmonids. A small improvement in water quality in the lower pool of the pit might be realized by a small weir or similar structure placed in the constriction between the middle and lower pools to increase the velocity of water flowing into the lower pool. A more general improvement might be gained by using short-term releases of water from upstream reservoirs in sufficient amounts to move stagnant water through the pit. But the most effective long-term improvement to water quality in the pit during low-flow periods is the continued reduction of effluent from upstream sources.

48. The potential negative effects of the excavation pit on salmonids (e.g., poor water quality and high predation) are likely to be greatest in the vicinity of the pit and diminish with increased distance away from the excavation site. The pit should not greatly affect movements of adult Atlantic salmon or of native or planted trout. However, predation on juvenile salmonids would decrease their abundance near the pit though consumption rates cannot be accurately predicted from available information. From the standpoint of a put-and-take trout fishery, the pit may yield a lower return than more desirable habitats. However, the excavation pit could easily and effectively be managed for the lacustrine species that currently thrive there. It may be desirable to integrate these species into a diversified fishery management program for the Naugatuck River. Unexcavated reaches, particularly those further upstream where water quality is less affected by effluent, may provide more suitable locations for salmonid management.

REFERENCES

Bartnik, V. G. 1970. "Reproductive Isolation Between Two Sympatric Dace, *Rhinichthys atratulus* and *R. cataractae*, in Manitoba," Journal of the Fisheries Research Board of Canada, Vol 27, pp 2125-2141.

Bell, M. C. 1973. "Fisheries Handbook of Engineering Requirements and Biological Criteria," prepared for US Army Engineer Division, North Pacific, Portland, OR.

Burdick, G. E., Lipschuetz, M., Dean, H. F., and Harris, E. F. 1954. "Lethal Oxygen Concentrations for Trout and Smallmouth Bass," New York Fish and Game Journal, Vol 1, pp 84-97.

Carlander, K. D. 1969. "Handbook of Freshwater Fishery Biology; Volume 1," The Iowa State University Press, Ames, IA.

Carlander, K. D. 1977. "Handbook of Freshwater Fishery Biology; Volume 2," The Iowa State University Press, Ames, IA.

Cherry, D. S., Dickson, K. L., Cairns, J., and Stauffer, J. R. 1977. "Preferred, Avoided, and Lethal Temperatures of Fish During Rising Temperature Conditions," Journal of the Fisheries Research Board of Canada, Vol 34, p 239.

Copes, F. A. 1978. "Ecology of the Creek Club," University of Wisconsin, Stevens Point Museum of Natural History Report on the Fauna and Flora of Wisconsin, No. 12.

Danie, D. S., Trial, J. G., and Stanley, J. G. 1984. "Species Profiles: Life Histories and Environmental Requirements of Coastal Fish and Invertebrates (North Atlantic)-Atlantic Salmon," FWS/OBS-82/11.22, US Fish and Wildlife Service, Technical Report EL-82-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Decola, J. N. 1975. "Atlantic Salmon Restoration and the Question of Water Quality," International Atlantic Salmon Foundation Special Publication Series, Vol 6, pp 24-28.

Doudoroff, P. W., and Shumway, D. L. 1970. "Dissolved Oxygen Requirements of Freshwater Fishes," Food and Agriculture Organization Fisheries Technical Paper No. 86.

Garside, E. T., and Tait, J. S. 1958. "Preferred Temperature of Rainbow Trout (*Salmo gairdneri* Richardson) and Its Unusual Relationship to Acclimation Temperature," Canadian Journal of Zoology, Vol 36, pp 563-567.

Gibson, R. J. 1966. "Some Factors Influencing the Distribution of Brook Trout and Atlantic Salmon," Journal of the Fisheries Research Board of Canada, Vol 23, pp 1977-1980.

Hartman, G. F., and Gill, C. A. 1968. "Distributions of Juvenile Steelhead and Cutthroat Trout (*Salmo gairdneri* and *S. clarki clarki*) Within Streams of Southwestern British Columbia," Journal of the Fisheries Research Board of Canada, Vol 25, pp 33-48.

Hilsenhoff, W. L. 1987. "An Improved Biotic Index of Organic Stream Pollution," Great Lakes Entomologist, Vol 4, pp 31-40.

Love, R. H. 1971. "Dorsal-Aspect Target Strength of an Individual Fish," Journal of the Acoustical Society of America, Vol 49, pp 816-823.

MacDonald, A. 1988. "The Physical Environmental Effects of Sand and Gravel Extraction in the Naugatuck River and Adjacent Floodplain," Internal Working Document EL-88-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Marshall, T. L., and MacCrimmon, H. R. 1970. "Exploitation of Self-sustaining Ontario Stream Populations of Brown Trout (*Salmo trutta*) and Brook Trout (*Salvelinus fontinalis*)," Journal of the Fisheries Research Board of Canada, Vol 27, pp 1087-1102.

McCauley, R. W., Elliot, J. R., and Read, L. A. 1977. "Influence of Acclimation Temperature on Preferred Temperature in Rainbow Trout, *Salmo gairdneri*," Transactions of the American Fisheries Society, Vol 106, pp 362-365.

Mills, D. 1971. Salmon and Trout: A Resource, Its Ecology, Conservation, and Management, St. Martin's Press, New York.

Morrissey, T., and Mauger, A. 1988. "Water Quality Analysis of the Upper Naugatuck River," Connecticut Department of Environmental Protection, Water Compliance Branch, Hartford, CT.

Mount, D. I., Norberg-King, T. J., and Steen, A. E. 1986. "Validity of Effluent and Ambient Toxicity Tests for Predicting Biological Impact, Naugatuck River, Waterbury, Connecticut," Report No. EPA/600/8-86/005, US Environmental Protection Agency, Duluth, MN.

Needham, P. R. 1969. Trout Streams, revised edition, Carl F. Bond, ed., Winchester Press, New York.

Raleigh, R. F. 1982. "Habitat Suitability Index Models: Brook Trout," FWS/OBS-82/10.24, US Department of the Interior, Fish and Wildlife Service.

Raleigh, R. F., Zuckerman, L. D., and Nelson, P. C. 1986. "Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout," Revised, Biological Report 82(10.124), US Fish and Wildlife Service.

Robbins, C. R., Bailey, R. M., Bond, C. E., Brooker, J. R., Lachner, E. A., Lea, R. N., and Scott, W. B. 1980. "A List of Common and Scientific Names of Fishes from the United States and Canada," 4th ed., Special Publication No. 12, American Fisheries Society, Bethesda, MD.

Scott, W. B., and Crossman, E. J. 1973. "Freshwater Fishes of Canada," Fisheries Research Board of Canada, Bulletin 184, Ottawa, Canada.

Tebo, L. B., Jr. 1975. "Review of Selected Parameters of Trout Stream Quality," Symposium on Trout Habitat Research and Management Proceedings, US Forestry Service, Southwest, Forestry Experiment Station, Asheville, NC, pp 20-32.

Twomey, K. A., Williamson, K. L., and Nelson, P. C. 1984. "Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker," FWS/OBS-82/10.64, US Fish and Wildlife Service, Washington DC.

US Environmental Protection Agency. 1987 (Jul). "Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates," draft report, USEPA Office of Water Quality.

Whitworth, W. R., Berrien, P. L., and Keller, W. T. 1968. "Freshwater Fishes of Connecticut," Bulletin No. 101, State Geological and Natural History Survey, Connecticut Department of Environmental Protection, Hartford, CT.

Table 1

Flow Duration Summary and Daily Discharge Levels in the Naugatuck River for the Days Preceding Fish and Water Quality Sampling

% of Time Exceeded	Flow Duration Exceedance Level, cms: Thomaston*	Flow Duration Exceedance Level, cms: Beacon Falls**	Day†	Discharge During Study Period, cms — Mean Daily Discharge, cms: Thomaston	Discharge During Study Period, cms — Mean Daily Discharge, cms: Beacon Falls
10	12.2	31.1	9	0.5	3.1
25	6.2	17.0	10	0.5	2.6
50	3.1	8.5	11	0.4	2.5
75	1.2	4.8	12	0.7	4.1
90	0.7	2.8	13	1.6	3.3
			14	1.1	3.4
			15	0.9	5.3
			16	0.7	3.3
			17	0.8	3.4
			18	2.3	6.1
			19	1.3	5.4
			20	3.2	10.1
			21	6.9	17.3
			22	3.6	12.3

* Based on 7,670 days of discharge readings, 1961-1981.
** Based on 21,550 days of discharge readings, 1919-1981.
† Field collections were made 18-22 July 1988.

Table 2

Water Quality Characteristics in the Excavation Pit and Adjacent Riffle Habitats

		7/20/88, 1500-1630 hr							7/21/88, 1200-1330 hr						
Location	Sample ID	Depth m	Temp °C	DO mg/ℓ	Ammonia mg/ℓ	pH	Conductivity µmho	Turbidity NTU	Depth m	Temp °C	DO mg/ℓ	Ammonia mg/ℓ	pH	Conductivity µmho	Turbidity NTU
Upper Riffle	01								0.0	21.2	8.5	0.70	6.7	150	21
Upper Pool	02	0.0S*	20.3	6.9	.	5.6	233		0.0S	21.7	8.0	.	6.6	173	
		3.0B	21.4	6.6	.	5.7	244		2.5B	21.6	8.3	.	6.6	177	
	03	0.0S	20.9	6.6	0.70	5.5	241		0.0S	21.7	7.3	.	6.6	173	
		4.0B	20.9	5.7	1.00	5.6	240		2.5B	21.7	7.3	.	6.6	173	
	04	0.0S	21.5	6.0	0.75	5.6	243		0.0S	21.8	7.3	0.70	6.5	180	
		6.0B	20.0	2.3	1.10	5.3	365		3.0	21.7	7.9	.	6.5	177	
									6.0B	21.8	8.0	0.65	6.5	182	
Middle Pool	05								0.0S	21.9	7.5	.	6.4	182	
									2.5	21.9	7.7	.	6.5	182	
									5.0B	21.9	7.5	.	6.4	182	
	06	0.0S	22.0	6.4	.	5.7	252		0.0S	21.9	7.8	.	6.4	182	
		3.0B	22.0	6.0	.	5.7	252		4.0B	21.9	8.0	.	6.4	182	
	07	0.0S	22.4	5.2	1.30	5.7	250		0.0S	21.9	7.4	0.80	6.3	191	
		4.0	19.5	2.0	.	5.4	360		3.5	21.7	8.1	.	6.2	189	
		6.0	15.4	2.0	.	5.4	380		4.5	21.7	7.0	.	6.3	185	
		8.0B	13.0	1.3	2.30	5.4	434		5.5	21.2	6.8	.	6.0	189	
									7.0B	15.0	1.9	1.80	5.9	439	
Lower Pool	08	0.0S	22.1	5.3	.	5.6	255		0.0S	20.6	6.9	.	6.0	177	
		2.0	21.9	4.8	.	5.6	260		3.0B	20.7	6.9	.	6.0	178	
		4.0B	21.1	4.3	.	5.5	296								

(Continued)

* S indicates surface sample, B indicates bottom sample.

Table 2 (Concluded)

Location	Sample ID	7/20/88, 1500-1630 hr							7/21/88, 1200-1330 hr						
		Depth m	Temp °C	DO mg/ℓ	Ammonia mg/ℓ	pH	Conductivity μmho	Turbidity NTU	Depth m	Temp °C	DO mg/ℓ	Ammonia mg/ℓ	pH	Conductivity μmho	Turbidity NTU
Lower Pool (Cont.)	09	0.0S*	22.5	3.9	.	5.7	265		0.0S	20.7	6.8	.	5.9	182	
		3.0B	21.9	3.0	.	5.5	274		3.0B	20.8	7.0	.	6.0	183	
	10	0.0S	25.4	5.1	1.20	5.7	263		0.0S	20.5	6.3	0.80	.	193	
		2.5	21.4	4.5	.	5.4	266		2.5	20.4	6.2	.	5.7	184	
		5.0B	16.1	2.0	1.70	5.2	402		3.5	20.3	6.2	.	5.7	185	
									4.5	20.1	6.3	.	5.7	191	
									5.5	17.1	2.2	.	5.5	403	
									6.5B	15.0	2.0	>3.00	5.5	466	
Lower Riffle	11	0.0S	22.0	4.0	.	5.8	296	16							

* S indicates surface sample, B indicates bottom sample.

Table 3

Results of Analyses on Water Samples for Nutrients, Solids, Metals, and Selected Ether Substances and Properties*

Sample Location	Depth	pH	Alkalinity mg/ℓ	Hardness mg/ℓ	Chloride mg/ℓ	Solids				Total Phos-phorus
						Total	Fixed	Volatile	Suspended	
Upper riffle	S	7.5	28	52	40	200	95	110	20	0.34
Upper pool	S	7.5	29	54	40	320	140	90	23	0.35
	B	7.3	28	53	42	210	110	100	20	0.30
Lower pool	S	7.1	35	52	65	210	130	80	4	0.31
	B	7.0	54	78	100	310	210	100	7	0.21
Lower riffle	S	7.1	38	57	70	230	150	80	4	0.32

Sample Location	Nitrogen, mg/ℓ				5-Day BOD	Total Metals, mg/ℓ							
	Organic	Ammonia	Nitrate	Nitrite		AS	CD	CR	CU	NI	PB	HG	ZN
Upper riffle	0.60	0.36	4.5	0.10	6	0	0.01	0.00	0.04	0.07	0.00	0	0.04
Upper pool	0.60	0.48	5.0	0.12	6	0	0.01	0.00	0.03	0.05	0.00	0	0.02
	0.80	0.48	5.2	0.13	6	0	0.01	0.00	0.04	0.04	0.02	0	0.02
Lower pool	0.48	0.54	3.2	0.15	7	0	0.01	0.01	0.03	0.05	0.03	0	0.01
	0.60	3.00	4.7	0.04	10	0	0.01	0.00	0.03	0.07	0.04	0	0.01
Lower riffle	0.60	0.80	3.3	0.14	8	0	0.01	0.00	0.02	0.06	0.00	0	0.02

* Samples analyzed by Connecticut Department of Health. Used with permission from Connecticut Department of Environmental Protection.

Table 4

Common and Scientific Names of Fish Taxa Collected in the Study

Common Name	Scientific Name	Primary Habitat* Lotic S	Lotic R	Lotic A	Lentic S	Lentic R	Lentic A
American eel	*Anguilla rostrata*			X			
Brook trout	*Salvelinus fontinalis*	X	X	X			
Chain pickerel	*Esox niger*				X	X	X
Common shiner	*Notropis cornutus*	X	X	X			
Golden shiner	*Notemigonus crysoleucas*				X	X	X
Spottail shiner	*Notropis hudsonius*				X	X	X
Creek chub	*Semotilus atromaculatus*	X	X	X			
Fallfish	*Semotilus corporalis*	X	X	X			X
Blacknose dace	*Rhinichthys atratulus*	X	X	X			
Longnose dace	*Rhinichthys cataractae*	X	X	X			
White sucker	*Catostomus commersoni*	X	X	X			X
Brown bullhead	*Ictalurus nebulosus*			X	X	X	X
Redbreast sunfish	*Lepomis auritus*			X	X	X	X
Rock bass	*Ambloplites rupestris*	X	X	X			X
Pumpkinseed sunfish	*Lepomis gibbosus*	X	X	X			X
Bluegill	*Lepomis macrochirus*				X	X	X
Smallmouth bass	*Micropterus dolomieui*		X	X	X		
Largemouth bass	*Micropterus salmoides*				X	X	X
Yellow perch	*Perca flavescens*				X	X	X
Tesselated darter	*Etheostoma olmstedi*	X	X	X			X

* Primary habitat locations are grouped according to life stage (S = spawning, R = rearing, A = adult) nomenclature after Robbins et al. 1980).

Table 5

Numbers and Taxonomic Composition of Fish Collected from the Excavation Site* and Nearby Riffle Habitat**

Common Name	Excavation Habitat				Riffle Habitat			
	Boat Shocker		Gill Net		Hoop Net		Seine/Shock	
	Number	%	Number	%	Number	%	Number	%
American eel	1	0.5	-	-	-	-	-	-
Common shiner	-	-	-	-	-	-	2	0.2
Golden shiner	-	-	18	6.3	-	-	1	0.1
Spottail shiner	-	-	-	-	-	-	21	2.5
Fallfish (chubs)†	-	-	1	0.4	3	5.0	39	4.7
Blacknose dace	-	-	-	-	-	-	81	9.7
Longnose dace	-	-	-	-	-	-	119	14.3
White sucker	53	26.5	66	23.2	1	1.7	368	44.1
Brown bullhead	1	0.5	2	0.7	3	5.0	-	-
Bluegill	5	2.5	-	-	-	-	-	-
Pumpkinseed sunfish	28	14.0	-	-	6	10.0	2	0.2
Redbreast sunfish	6	3.0	1	0.4	-	-	-	-
Rock bass	13	6.5	10	3.5	39	65.0	-	-
Largemouth bass	84	42.0	-	-	-	-	97	11.6
Smallmouth bass	-	-	-	-	6	10.0	-	-
Yellow perch	5	2.5	186	65.5	2	3.3	-	-
Tessellated darter	4	2.0	-	-	-	-	105	12.6
TOTALS	200	100.0	284	100.0	60	100.0	835	100.0
TOTAL TAXA	10		7		7		10	
	(12)††				(14)††			

* Excavation site totals include all pools.

** Riffle habitat totals include the lower, middle, and uppper riffles in and immediately adjacent to the excavation pool.

† A total of 41 specimens collected during the study were later identified to species as creek chub (26) and fallfish (15).

†† Numbers in parentheses are the total number of taxa collected in each of the two major habitat types.

Table 6

Summary of Fish Length Measurements in Millimetres

	Excavated Pools						Riffle Habitats		
	Boat Shocker			Gill Net			Hoop Net		
Species	N	Range	Mean	N	Range	Mean	N	Range	Mean
American eel	1	800-800	800	-	-	-	-	-	-
Golden shiner	-	-	-	18	175-265	205	-	-	-
Fallfish	-	-	-	1	210-210	210	3	150-150	150
White sucker	53	54-405	332	66	210-390	327	1	300-300	300
Brown bullhead	1	335-335	335	2	260-350	305	3	175-280	235
Bluegill	5	80-149	120	-	-	-	-	-	-
Pumpkinseed sunfish	28	66-195	109	-	-	-	6	130-200	164
Redbreast sunfish	6	69-150	104	1	130-130	130	-	-	-
Rock bass	13	86-158	112	10	135-215	170	39	130-230	166
Largemouth bass	84	33-360	72	-	-	-	-	-	-
Smallmouth bass	-	-	-	-	-	-	6	215-230	223
Yellow perch	5	81-215	168	186	150-290	209	2	225-240	233

Table 7

Vertical Distribution of Fish Detected With Hydroacoustic Sampling in the Excavation Pit*

Depth Strata of Fish m	Percent Distribution of Fish in Water Column By Bottom Depth												
	Upper Pool Bottom Depth, m							Lower Pool Bottom Depth, m					
	1-2	2-3	3-4	4-5	5-6	6-7	7-8	1-2	2-3	3-4	4-5	5-6	6-7
1-2	-	44	28	14	0	0	0	100	36	0	21	0	0
2-3		56	72	31	21	22	11		64	39	20	9	9
3-4			0	46	34	15	0			61	38	37	30
4-5				10	38	27	18				22	46	34
5-6					7	36	38					7	23
6-7						0	34						4
7-8													
Total	-	100	100	101	100	100	100	100	100	100	101	99	100
Total fish detections	0	13	14	53	61	42	20	1	3	9	17	31	17

* On the day of sampling, no stratification was identified in the upper pool; a thermocline at approximately 5 m was detected in the lower pool.

Table 8

Number, Taxonomic Composition, and Catch per Unit Effort of Fish Collected in Each Riffle Area and Near Torrington

Common Name	Lower Riffle				Middle Riffle				Upper Riffle				Torrington	
	Hoop Net		Seine/Shock		Hoop Net		Seine/Shock		Hoop Net		Seine/Shock		Seine/Shock	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Brook trout	-	-	-	-	-	-	-	-	-	-	-	-	10	7.5
Chain pickerel	-	-	-	-	-	-	-	-	-	-	-	-	1	0.8
Common shiner	-	-	-	-	-	-	1	0.2	-	-	1	0.9	-	-
Golden shiner	-	-	1	0.7	-	-	-	-	-	-	-	-	-	-
Spottail shiner	-	-	1	0.7	-	-	17	2.9	-	-	3	2.7	-	-
Fallfish (chubs)*	2	7.4	8	5.5	-	-	27	4.7	1	50.0	4	3.6	1	0.8
Blacknose dace	-	-	68	46.9	-	-	8	1.4	-	-	5	4.5	7	5.3
Longnose dace	-	-	2	1.4	-	-	35	6.0	-	-	82	73.9	1	0.8
White sucker	-	-	2	1.4	1	3.2	365	63.0	-	-	1	0.9	9	6.8
Brown bullhead	-	-	-	-	2	6.5	-	-	1	50.0	-	-	6	4.5
Bluegill	-	-	-	-	-	-	-	-	-	-	-	-	11	8.3
Pumpkinseed sunfish	-	-	1	0.7	6	19.4	1	0.2	-	-	-	-	7	5.3
Redbreast sunfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rock bass	19	70.4	-	-	20	64.5	-	-	-	-	-	-	-	-
Largemouth bass	-	-	18	12.4	-	-	74	12.8	-	-	5	4.5	52	39.1
Smallmouth bass	6	22.2	-	-	-	-	-	-	-	-	-	-	-	-
Yellow perch	-	-	-	-	2	6.5	-	-	-	-	-	-	-	-
Tessellated darter	-	-	44	30.3	-	-	51	8.8	-	-	10	9.0	28	21.1
Total	27	100.0	145	100.0	31	100.0	579	100.0	2	100.0	111	100.0	133	100.0
Total taxa	3		9		5		9		2		8		11	
Sample size	3		20		3		20		4		20		20	
Fish per sample	1-25		2-14		2-18		3-219		0-1		1-20		0-24	
Catch per effort**	9.00		7.25		10.33		28.95		0.50		6.33		5.55	
Standard deviation	13.86		4.01		8.02		54.07		0.58		5.12		5.82	

* Sample contains creek chubs and fallfish.

** Hoop net: fish per net night; seine/shock: fish per 9.3 sq m of surface area.

Table 9

Benthic Invertebrates Collected at the Upper and Lower Riffles Adjacent to the Excavation Pit*

Taxa	Upper Riffle		Lower Riffle	
	Rapid Assessment	Nonquantitative	Rapid Assessment	Nonquantitative
Diptera				
Antocha spp.	6	1	p**	1
Hemerodromia spp.	1	-	-	1
Simulium spp.	-	-	-	-
Cardiocladius obscurus	2	2	15	2
Chironomus spp.	-	-	-	2
Cricotopus intersectus	2	-	-	-
Cricotopus bicinutus	-	-	4	3
Parachironomus frequens	-	-	1	-
Polypedilum convictum	1	-	7	-
Polypedilum illinoense	3	-	-	1
Rheotanytarsus spp.	p	-	-	-
Dicrotendipes neomodestus	p	-	4	1
Unidentified Chironomidae	-	2	-	-
Trichoptera				
Ceratopsyche bifida	16	2	15	2
Cheumatopsyche spp.	33	17	79	15
Hydropsyche betteni	10	5	12	4
Leucotrichia spp.	3	4	p	10
Unidentified Hydropschidae	-	1	2	2
Ephereroptera				
Baetis intercalaris	9	8	-	-
Pseudocloeon spp.	12	1	p	3
Megaloptera				
Corydalus cornutus	2	-	p	-
Sialis spp.	p	2	-	-
Coleptera				
Stenelmis spp.	1	-	-	-
Berosus spp.	p	2	-	3
Hydrochus spp.	-	-	-	2
Gastropoda				
Physa heterostropha	9	1	-	3
Helisoma anceps	-	5	3	2
Helisoma trivolvis	-	-	1	-

(Continued)

* Two kicknet samples at each site included a 1-sq-m semi-quantitative sample and a qualitative sample of all available habitats. (Results of benthic samples collected and analyzed by Connecticut Department of Environmental Protection Water Compliance Unit. Used with permission.)

** P indicates presence of benthic invertebrates.

Table 9 (Concluded)

Taxa	Upper Riffle		Lower Riffle	
	Rapid Assessment	Nonquantitative	Rapid Assessment	Nonquantitative
Hirudinea				
Erpobdella punctata punctata	-	3	-	-
Bivalvia				
Unidentified Sphaeridae	-	-	1	2
Other				
Prostoma rubrum	-	1	-	1
Unidentified Planarians	-	-	-	4
Total taxa	23		24	

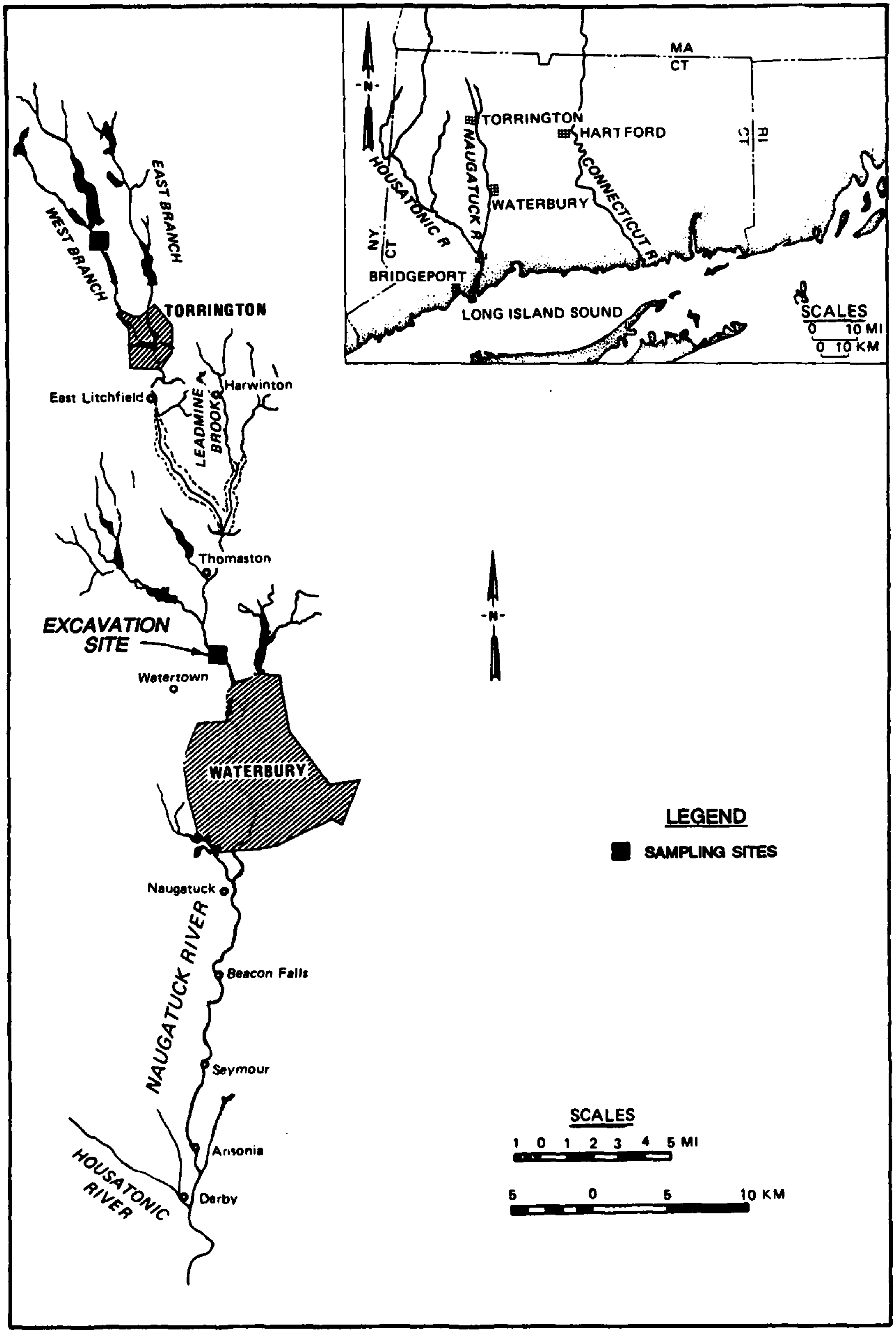

Figure 1. Location of Naugatuck River study area and field collection sites

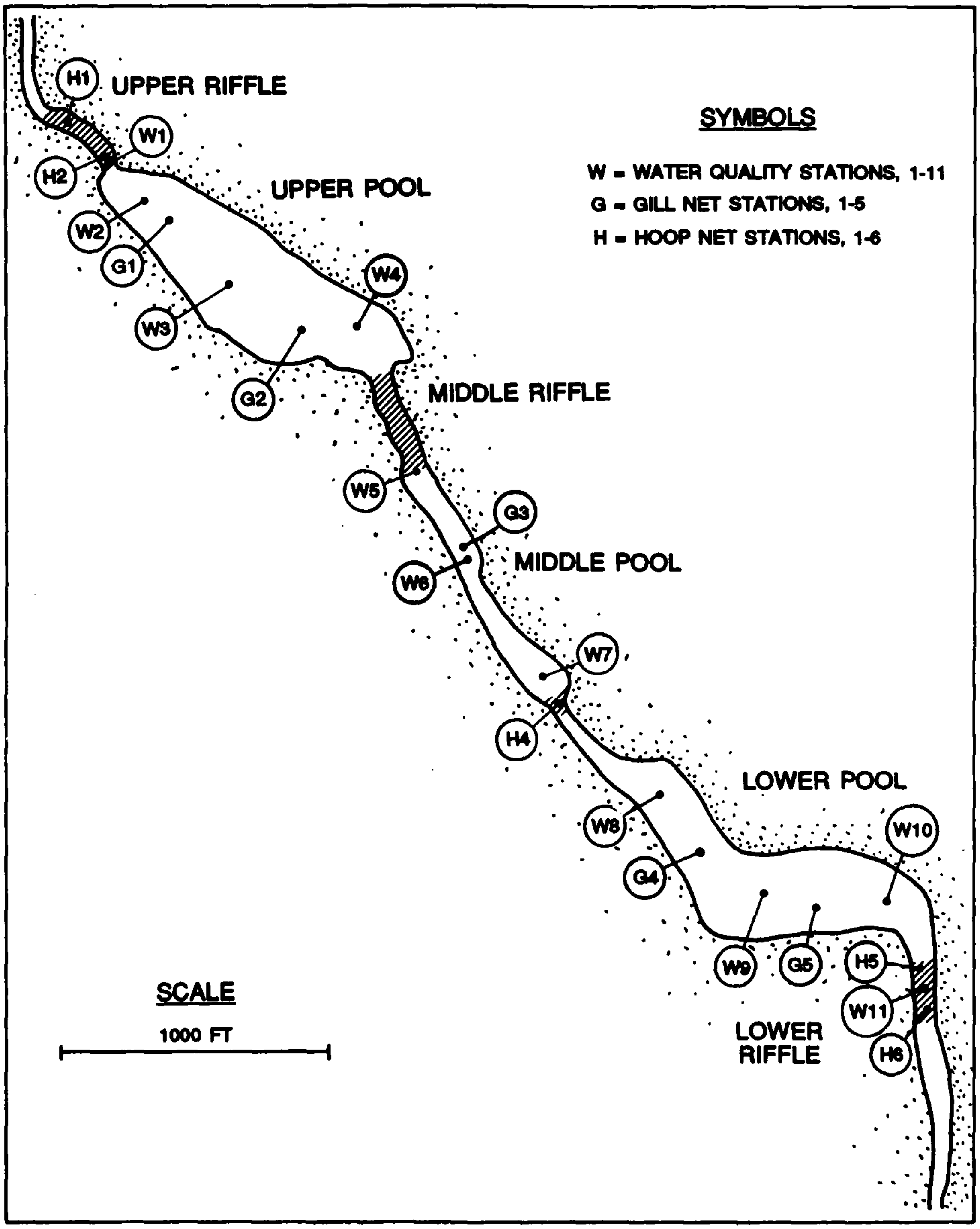

Figure 2. Diagram of the excavation pit with locations of water quality and fish sampling stations

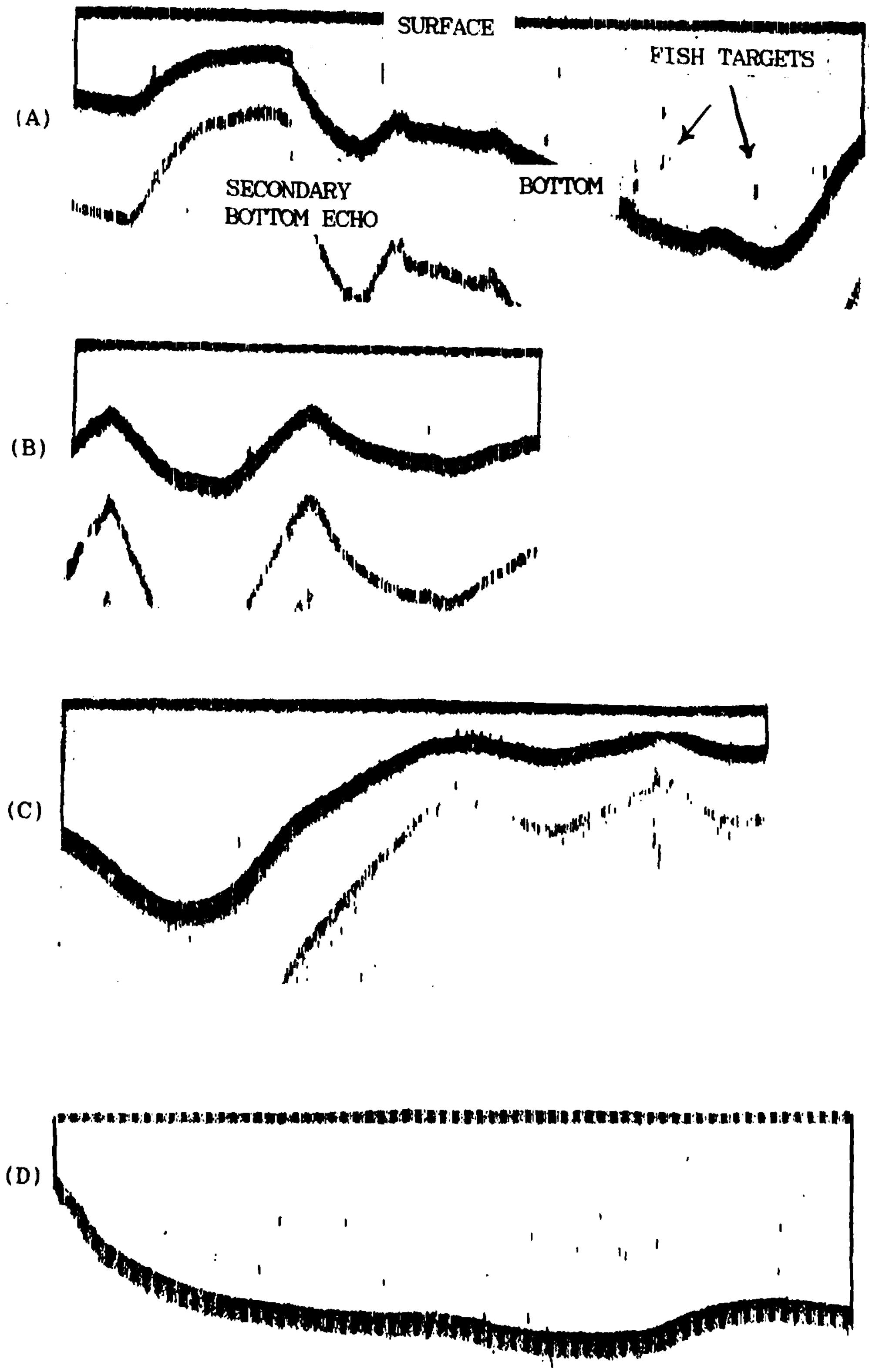

Figure 3. Acoustic echograms of pit bottom profiles and fish detections. (A) and (B) are river cross-sections in the upper pool, (C) is a cross-section of the lower pool, and (D) shows a short reach of the lower pool

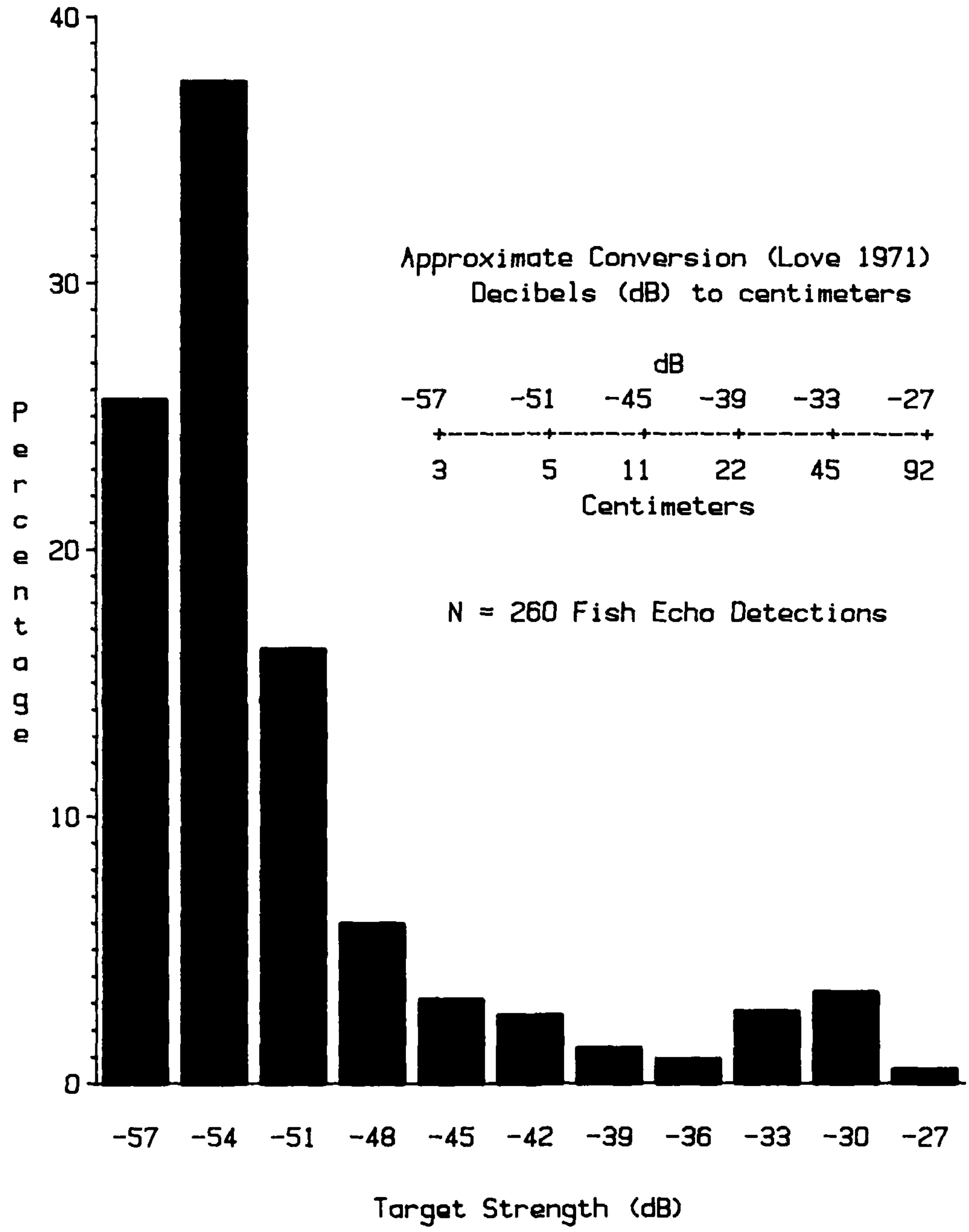

Figure 4. Acoustically estimated size distribution of fish in the excavation pit